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A NEW BROOM makes a clean sweep, but it may serve sometimes to carry a pest into the house. The European corn borer, which sailed into this country like a stow-away, hidden in the heart of broom corn from across the water, has now settled down in America, probably to stay. It extends its infestation over a widely broken belt of territory, from the coast of Massachusetts and New Hampshire on the east through east-central and western New York (fig. 1) to a point beyond St. Thomas in western Ontario, Canada. The total area inhabited by the pest within the United States is about 4,500 square miles, and in Canada it is probably not less than 3,000 square miles.

This insect is apparently a native of central Europe or Asia; at least it has long been known as a harmful insect in those portions of the globe. In Italy, Austria, and France it has been considered for many years a serious enemy of the maize or Indian corn plant. Maize seems to be its preferred food plant at present, although, as this plant is of American origin, its native or original host must have been some similar species, probably some one of the larger Asiatic or European grasses or grasslike plants. The insect seems to be able to subsist upon almost all herbaceous plants, and in this country has already been recorded as feeding on no

less than 167 kinds of plants, both wild and cultivated. Among the more important of these from an economic standpoint are corn of many varieties, celery, beans, beets, and rhubarb. Corn is the crop that sustains by far the greatest commercial damage (fig. 2), although recently the insect has been found to infest celery in the Boston region so seriously as to prevent its certification for shipment to the most profitable market. This pest also infests such commercially important flowering plants as gladioli, cosmos, hollyhocks,

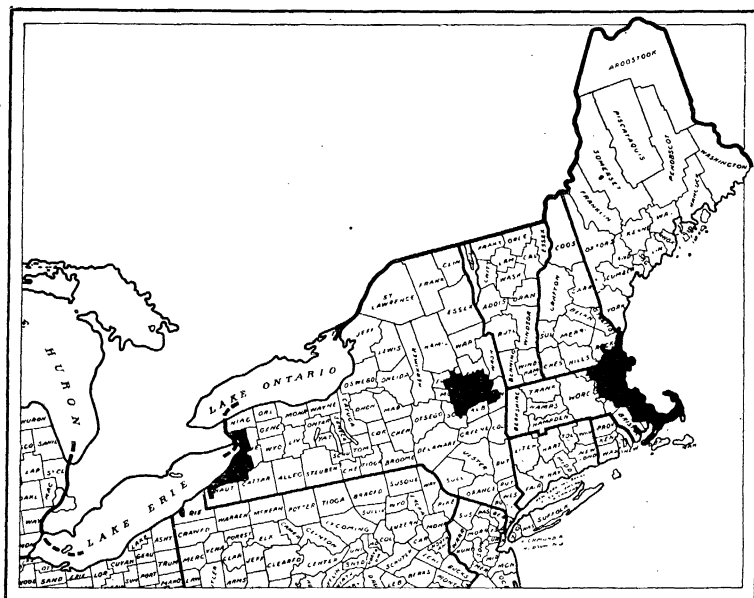
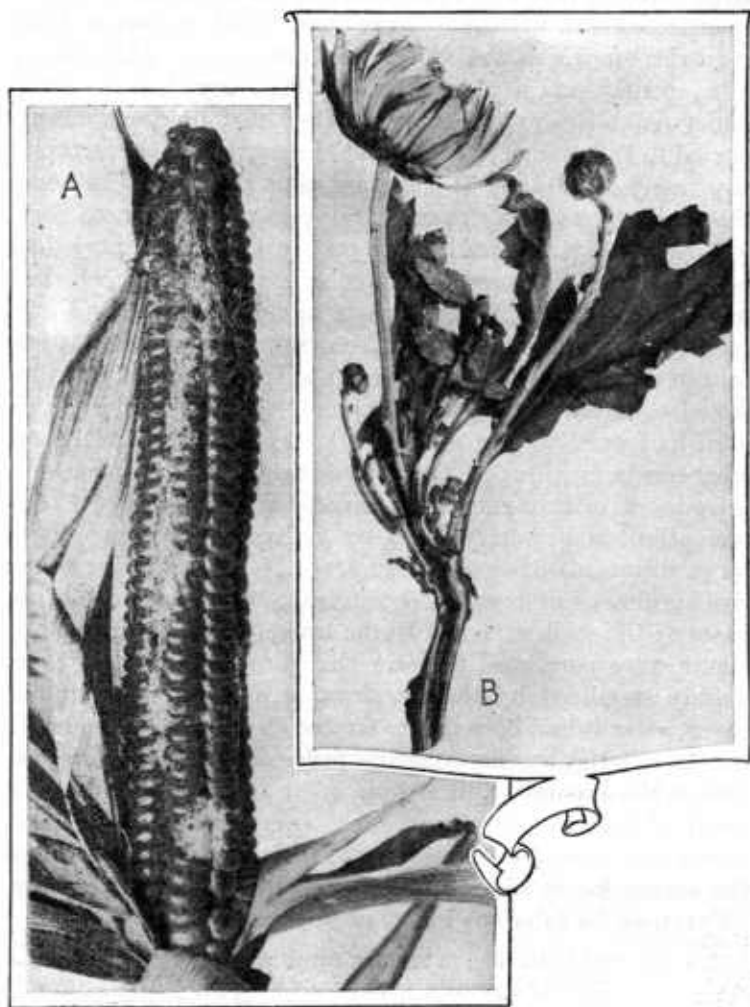


FIG. 1.—Known distribution of the European corn borer in the United States, on November 1, 1920.

hardy chrysanthemums (fig. 2), and asters, while dahlias are very seriously injured where infestation is unusually heavy and these highly ornamental plants are grown in proximity to corn. A few woody plants, such as elder and raspberry, are occasionally found infested.

Getting Past the Customhouse.

When the corn borer was first discovered in eastern Massachusetts during the summer of 1917, it was supposed that it had entered the country hidden in the stems of raw hemp,



In Corn and Chrysanthemum.

FIG. 2.—A, Typical infestation of an ear of flint field corn by the European corn borer; the white, powdery material is a combination of mold and castings of the insect. B, Chrysanthemum, with caterpillar of the European corn borer within the stems at lower end.

which is one of its numerous food plants in Europe. A large cordage factory in the center of the area first found to be infested was known to have used hemp imported from countries in which the insect was numerous. This theory subsequently was weakened by the discovery that the hemp underwent a severe process called "retting" before it was exported to this country, which would destroy almost certainly any insect inhabitant of the plant thus treated. The hemp theory soon gave way upon the discovery that broom corn, which is badly infested by the pest in the old country, had been imported and used by factories located near the foci of infestation in both Massachusetts and New York, and customs records were unearthed showing that at least 10,000 tons of such material had entered the United States from infested countries during the period 1909-1914, and that this corn had been widely distributed throughout many States where corn is grown. The supposition that the insect was introduced in this manner received confirmation by the interception, in February, 1920, by Federal inspectors, of two large shipments of broom corn from Italy containing many live specimens of corn-borer caterpillars hidden within the parts of the stalk attached to the brush. Before these shipments were permitted to enter the country they were thoroughly sterilized by the introduction of live steam under cover, after it had been demonstrated that sterilization could not be effected by the ordinary methods of fumigation, except at the expense of incredible labor and extreme cost. In point of fact the European corn borer seems to be a most hardy and tenacious creature, and this doubtless influenced the entomologist who named the group to which it belongs "*Pyrausta*," a fabulous insect of Grecian mythology.

"So in the fire, in burning furnace, springs
The fly *Pyrausta* with flaming wings;
Without the fire it dies; in it it joys;
Living in that which all things else destroys."

—*Du Bartas.*

The reader will wonder perhaps, since the Government maintains a corps of inspectors to examine all importations of such character, why the original infestation was not prevented in a similar manner, but this is easily explained by

the fact that this inspection service was not authorized by law until 1913, or several years subsequent to the probable introduction of the pest. It is true, moreover, that, even where an efficient corps of trained inspectors is employed, it is impossible for them to examine every shred of each plant, bale, or bundle so thoroughly as to prevent the entry of at least a few insects. For this reason the Federal Horticultural Board is extending supervision, as rapidly as available funds permit, to the importation of all plants or plant products which are deemed likely to convey insect or other pests dangerous to agriculture from foreign countries into the United States. Most of the insect pests of foreign origin now inhabiting the United States have entered the country through the avenues of commerce, and in view of the great damage inflicted on American agriculture by such introduced insects as the San Jose scale, the gipsy moth, the alfalfa weevil, the pink bollworm, and, last but not least, the Hessian fly, the necessity for some such action seems perfectly obvious.

How can an injurious insect like the corn borer exist in the United States for so long a period as from seven to eight years without detection? The answer to this natural and highly pertinent question is not difficult to find.

Assuming that several adults of the corn borer, male and female, succeeded in emerging from their hiding places in the stalks of broom corn in a given locality, only a few of these might find their way to growing corn or other plants suitable for the deposition of the eggs. Others might die without the opportunity of mating, while practically all of them would be exposed to innumerable perils from predacious enemies such as birds, predatory insects, etc. Thus in the beginning an exceedingly slight infestation would result. Moreover, it seems to be a well-established habit of the pest to refrain at first from seriously attacking the ears of the corn, and to confine its work chiefly to the tassel and upper portions of the stalk. Then, as it becomes more abundant, it works lower down in the stalks, finally attacking the ears and even entering the rootstocks wherever heavy infestation occurs. Thus it may easily be seen that, as a result of these peculiar habits, the insect might be present in a corn-growing center for a very considerable time without materially reducing the crop or attracting the attention

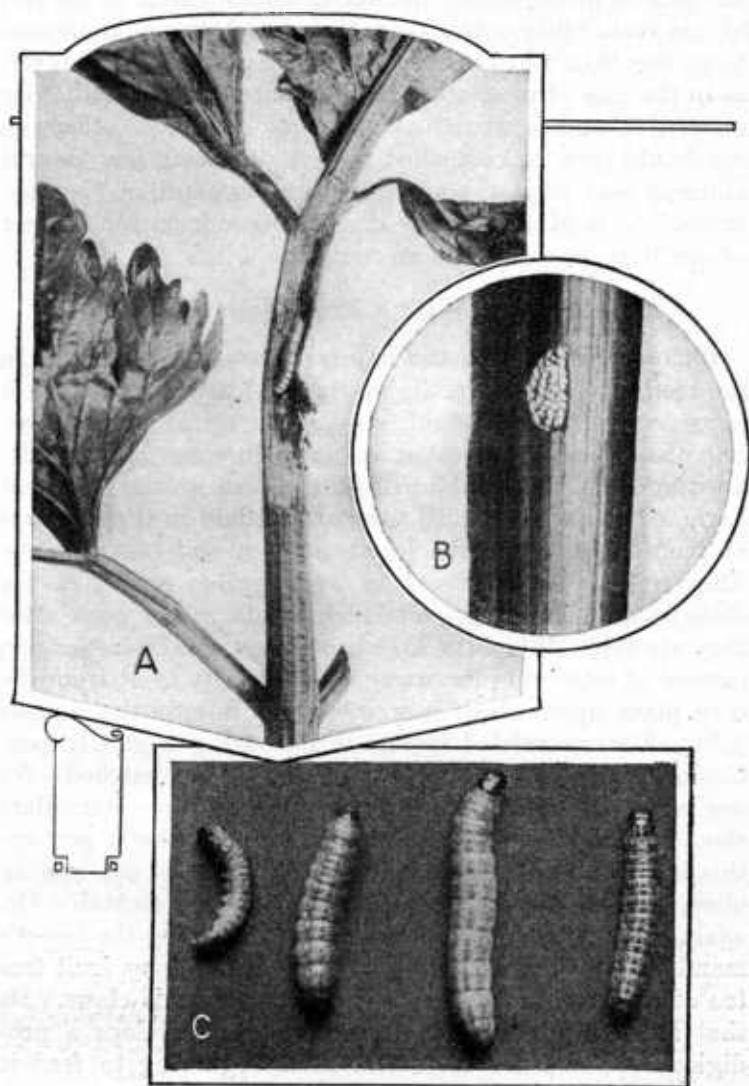
of the farmer, who is not inclined to look for trouble or to complain of an insect pest until it appears in numbers sufficient materially to reduce the yield. Undoubtedly this is just what occurred in the case of the European corn borer. The insect was first discovered in the summer of 1917 by Mr. Stewart Vinal, an entomological investigator who had been assigned by the Massachusetts State Agricultural Experiment Station to aid the market gardeners of the environs of Boston in the suppression of insect pests attacking garden crops. Although gardeners had noticed the caterpillar (fig. 3) in sweet corn for several years, it had not, up to that time, interfered seriously with either the yield or the sale of that toothsome article of produce. Mr. Vinal recognized almost immediately the importance of his discovery, and the State authorities quickly enlisted the aid of the Federal Bureau of Entomology in an investigation of the pest. An account of these activities is given farther on in this article.

An Innocent-Looking Moth.

The adult or parent of the corn borer is a rather pretty and innocent-looking little moth or miller that flits about in the twilight, or early hours of the night (see fig. 4). As a rhymester has put it:

“Little moth on velvet wing,
Such an airy, fairy thing;
How can you so guileless look,
Yet rob the farmer's pocketbook?”

It is not like many other night-flying moths which are strongly attracted to light, but, on the contrary, is seldom seen except as the insect is flushed from the grass and weeds as one walks through the fields, where it occurs in considerable numbers at certain seasons of the year. The female moth is pale yellow in color, with smoky, irregular lines on its wings, and measures about an inch in expanse, while the male is slightly smaller and is pale smoky brown, with pale yellow spots on both front and hind wings. In eastern Massachusetts this little pest has two generations annually; that is to say, it “breeds” twice each year. The first “hatching” or “brood” of moths lays an average of 386 eggs each, and the second 550, so if we assume that they were equally di-



Caterpillar and Eggs.

FIG. 3.—A, Stalk of celery with side cut away to show caterpillar of corn borer within. B, Cluster of eggs of European corn borer on blade of corn. C, Caterpillars of the European corn borer in three stages of growth.

vided as to sex, and all survived, the progeny or children of one pair of moths would amount to 53,075 insects at the end of one year, while in two years their numbers would amount to no less than 2,816,406,625 worms. Fortunately, however, as in the case of most other insects, many enemies and other restrictive and destructive influences intervene, otherwise we should soon be compelled to give up eating our natural aliments and subsist upon corn-borer caterpillar "en caserole," "a la Maryland," or in some other form for the rest of our lives, or so long as we could stand it.

A Caterpillar With a Prodigious Appetite.

But to proceed with the natural history of the pest: In the moth stage the insect is not in the least injurious, as it takes no solid food, probably sipping the nectar from flowering plants as it flies about on its nefarious trade of depositing eggs where they will do the corn grower the most harm. These eggs (fig. 3) are flat and laid in little groups of from 15 to 20 on the leaves of corn and other plants. They are carefully placed in overlapping rows like the shingles on a building, and hatch in about one week after they are laid. When the little worm emerges from the egg, instead of beginning its career with a hearty meal from the corn plant upon which it was born, it follows the curious habit of many related insects in devouring a goodly portion of the shell of the egg from which it was hatched. No one has seen fit to explain just why these baby caterpillars should begin their diet with a course of eggshell; perhaps this is by way of a relish or appetizer, just as one eats an olive, or as, in historic times, one partook of a cocktail. Or, again, the shell may be of service in sharpening the insect's mandibles in the same way that a favorite young fruit tree too often serves a thomas cat in sharpening his claws. Be that as it may, the caterpillar very soon develops a prodigious appetite for corn, and after beginning to feed it eats and eats, for weeks on end, only stopping long enough to change its clothes when these become too small for it. This insect literally becomes too large for its skin, which it sheds in about the same way as a snake. During this process it takes no food, but devotes all its attention and energies to the business of peeling off its old skin, including even

its claws and bristles. This event occurs five times during the existence of the caterpillar. Soon after the fifth molt the insect becomes full grown and, at that time, is about an inch long and one-eighth of an inch thick. The head of the caterpillar (fig. 3) is dark brown or black, while the upper surface of the body or back varies from dark brown to pink. The underside, or belly, of the worm is flesh colored and without markings of any kind. This boring caterpillar bears no distinctive markings by which the ordinary observer might hope to recognize it, and even highly trained experts have at times been temporarily at a loss to distinguish the caterpillar from its nearest relatives inhabiting the same plants. These close relatives are several, but none of them, so far as known, is injurious to agriculture in any appreciable degree. In point of fact, some of them doubtless are beneficial, as they feed on the common weeds.

After about six weeks, when the caterpillar has fed to repletion and is full grown, it becomes stationary, shrinks slightly in length, sheds its skin for the sixth time, and transforms into a light-brown, shuttle-shaped object about three-fourths of an inch long. This is known as the pupa or resting stage of the insect. After the lapse of about two weeks the skin or shell of the pupa splits and the moth emerges. As the adult insect issues from its pupal envelope it is anything but a beautiful object—dull in color and bedraggled in appearance, with its wings crumpled up in little knots above the shoulders. It crawls to some safe perch, however, and in the course of an hour or two has assumed the graceful shape and pleasing colors which distinguish the species. Very soon it is able to mate, lay its eggs, and thus begin all over again the process of development described above.

This life history, or cycle, is repeated twice each year in the vicinity of Boston, Mass., the caterpillar produced by the second brood of moths spending the winter in its burrows within the plants upon which it has fed. Elsewhere in America, however, it is believed to undergo but one generation during the year. Such is the case in both eastern and western New York, although climatic and other conditions there apparently do not differ materially from those prevailing in eastern Massachusetts.



Corn Borer Injury to Various Plants.

FIG. 4.—Top at left: Larvæ and pupæ in cornstalks, and young tassel attacked by the insect. Male and female moths drawn on same scale as the corn. Top center: A female moth with cluster of eggs on a section of corn leaf, on a considerably larger scale. Top right: Mature tassel showing typical injuries by caterpillar (the broken tassel stem is often the most noticeable evidence of the presence of the insect during the early summer months). Center: External and internal views of injuries inflicted on two ears of sweet corn. Lower half of the plate: Snap beans, beets, and celery attacked by the borer, cornstalk containing caterpillars, corn stubbles cut away to show how the caterpillars hide themselves in the fall, winter, and early spring months, "smartweed," which is a favorite food at times, "barnyard grass," which in Massachusetts is often heavily infested, and "cocklebur" plant, a weed that often serves as a breeding place for the pest.

By Rail and Wing.

Although the adult moth flies readily, it is not what might be called a strong flier. Compared, for instance, with the cotton moth, the army worm moths, and other robust members of that family, some of which are known to fly for hundreds of miles, the moth of the corn borer has rather feeble powers of flight. The longest flight that has actually been recorded under experimental conditions is about 3,900 feet. Under favorable conditions, however, the moth might be carried for much longer distances and perhaps for many miles. Investigations during 1920 have made it plainly apparent that this spread by flight, or natural spread, as it is termed, is a comparatively slow process, although it can not be prevented. The means of distribution of the pest most greatly to be feared is its carriage by human agency; that is to say, by its shipment for distances, perhaps, of hundreds or even thousands of miles in crops such as corn, celery, rhubarb, or cut flowers. There is also grave danger of its being included in the material used for packing, such as cornstalks, corn leaves, or husks, and many other dried plants, as hay, for instance, containing large weed stems, etc.; and the quarantine measures which are being enforced by the Bureau of Entomology and the Federal Horticultural Board are aimed at preventing, so far as may be possible, the transportation of such dangerously infested material from the infested regions to portions of the country where the insect is believed not to exist. Especially vigorous efforts are being made to prevent such movement of the pest into the great corn-belt States of the Middle West.

Besides corn, the caterpillars feed also on many other cultivated plants (fig. 4) to a very considerable extent, wherever infestation is heavy. Of the plants thus infested, celery (fig. 3) is perhaps the most important from a commercial standpoint. Many hundreds of acres are planted to this crop in that part of Massachusetts most seriously infested by the insect, and the heavy infestation of this crop may therefore mean a serious loss to the large interests involved. During the summer of 1919 celery was observed to be infested principally in the outer leaves and stems, in which case the insect was easily detected, but at present it has been found to bore

directly into the heart of the plant in many instances, and thus render celery one of the most dangerous means of artificial distribution for this pest. This fact has made it necessary for the inspectors to refuse certification, for shipment outside of the infested area, to growers whose crops were found to be most heavily infested. Rhubarb, or pieplant, is another product of the garden which recently has become of importance as a means of spread, but in the case of this plant inspection and certification usually are possible because the stems are separated in preparing the vegetable for market.

These plants are mentioned especially to illustrate how such comparatively unimportant products may harbor and distribute an insect which is of prime importance to a fundamental crop such as Indian corn. It is in relation to corn, of course, that the insect is being most seriously considered by entomologists and others most deeply concerned in controlling or restricting the ravages of the pest. We will show presently that the extermination of this new and injurious pest is beyond the pale of possibility, and the next important question is: How can it be repressed and restricted in order to minimize the damage it can do?

Hard to Kill.

The first thought naturally is: We will poison it. This method has been tried without success, principally because the corn borer feeds within the stalks and ears of the plant, and can not be reached by the poison. Various cultural methods have also been tried without materially beneficial results.

The weak link in the chain of the creature's existence is the fact that it spends the late fall, winter, and early spring months as a caterpillar within the stems, rootstocks, and stubble of the plants upon which it has fed during the previous summer. Thus it seems obvious that if these could be destroyed or so treated as to kill the insects contained therein the desired results would be accomplished. Many caterpillars remain all winter in corn stubble in the fields (fig. 5), either in the stump of the stalk or in the rootstock below the ground, although the majority of them are concealed within the stalks or ears of the corn, even in the cobs. It has been found that the conversion of corn into ensilage de-

stroys all the worms contained therein, and for this reason growers within the infested regions are advised to adopt this method of disposal for their crops. Of course this method does not dispose of the insects remaining in the stubble, and

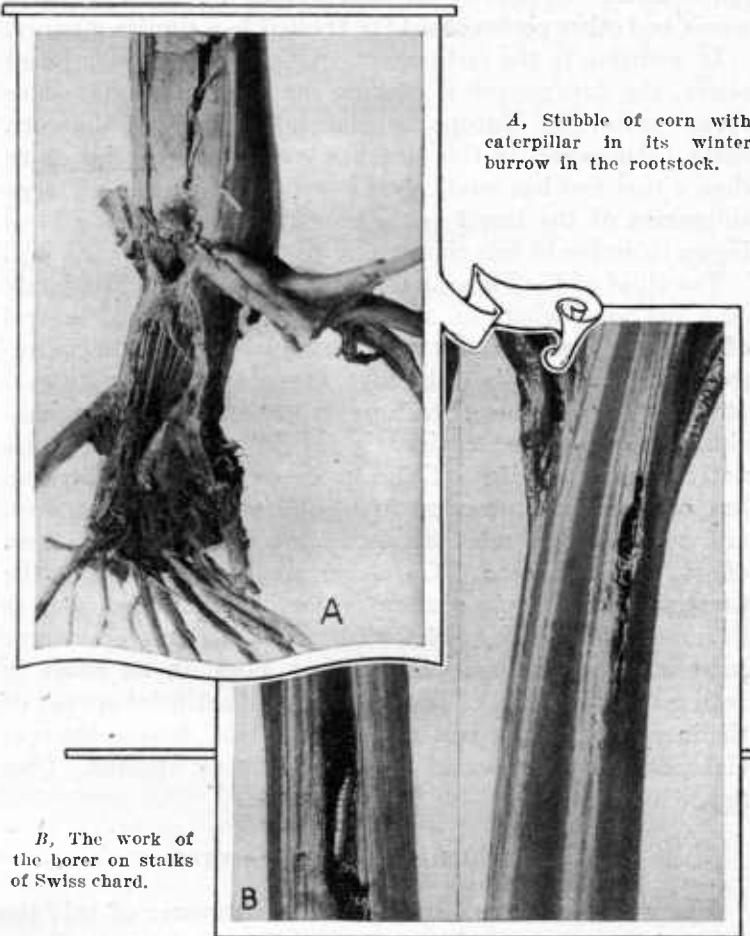


FIG. 5.—Work of the European corn borer.

for this reason corn stubble in infested territory should be cut at or as close to the surface of the soil as possible in order to remove as many caterpillars as possible from the fields. Where stalks and cobs are not made into ensilage some other effective method of disposal must be adopted if

this pest is to be successfully combated, and the only one that can be recommended at present is burning this material during the late winter, early spring, or sooner if the stalks are dry enough not to require excessive amounts of fuel to ignite them. In heavily infested regions the stems of coarse weeds and other plants should be treated in a similar manner.

In addition to the methods of artificial control mentioned above, the department is making every effort to introduce from continental Europe the natural enemies of the corn borer. An expert in this line has been in France for more than a year and has established a laboratory there, and large shipments of the insect parasites of the pest already have begun to arrive in this country.

The chief of the Federal Bureau of Entomology has lately been overseas, where he secured the cooperation of several of the most prominent European entomologists in this movement. He reports that although the pest is widely distributed in those portions of Europe where corn is grown in considerable quantities, it evidently is held well in check by its native insect parasites. This augurs well for the enterprise, but, of course, the process of parasite establishment is slow, and several years must elapse before the results of these efforts can be known. The department is engaged, at the present writing, in cleaning up by mechanical means, such as burning and crushing infested material, an area of intense infestation in extreme western New York, in an effort to reduce the likelihood of both natural and artificial spread of the insect to the corn-belt region. For this purpose the special machinery mentioned hereafter is being utilized. (See figs. 6 and 7.)

Government-Control Measures.

Upon the discovery of the pest in the summer of 1917 the Department of Agriculture was called upon to assist in an investigation of the insect in order to obtain information upon which to base efforts at control or possible eradication.

No fund is set aside by Congress to meet emergencies that may arise through the introduction of plant pests, but the Bureau of Entomology responded as well as it was able in the circumstances by establishing, in the spring of 1918, a



Control Measures.

FIG. 6.—Above: Warning banner at the edge of infested territory to prevent automobiles carrying infested plants into uninfested territory. Below: Destroying the corn borer by burning over infested weeds and grasses. Fuel oil is delivered to the nozzles of the burner at a pressure of 400 pounds to the square inch, creating a flame of intense heat directed toward the ground. The machine burns a strip about 15 feet wide.

small field force and laboratory in the center of the infestation at Arlington, Mass. Here, in cooperation with the Massachusetts State Agricultural College, were conducted investigations upon which was based the Farmers' Bulletin (No. 1046) which was issued the following April. At the

time that publication was prepared, the area infested was known to be at least 320 square miles in extent and the injuries caused by the insect to sweet corn indicated strongly that it might prove to be a corn pest of real if not of great importance. Realizing that a more thorough investigation should be made, the Secretary of Agriculture requested of Congress in September, 1918, the sum of \$25,000 for this purpose. In the meantime entomologists and agriculturists throughout the corn-growing regions of the country had become thoroughly and possibly unduly alarmed over the situation. A committee of State entomologists and other interested persons appeared before Congress requesting, in emphatic terms, an immediate appropriation of at least \$500,000



FIG. 7.—Special crushing machine used for treating green plants containing the borer. When infested plants are too green to burn readily they are run through the large corrugated rollers. These apply a pressure of about 40 tons, thus crushing all the insects contained therein.

for the purpose of exterminating the pest. The Sixty-fifth Congress expired without taking final action on either request. The department did not approve the request for the larger appropriation for purposes of extermination because it was convinced that this was impossible. The insect had become firmly established over a territory of several hundred square miles, embracing not only the city of Boston but many of its environs, and had demonstrated its ability to

subsist on a great variety of wild and cultivated plants. It was realized that to afford even a fair chance of extermination the expenditure of not thousands but millions of dollars would be necessary, and, as a mere incident to this expense, the reduction of the whole infested region to a desert must ensue. In other words, unlimited funds and unrestricted authority would be necessary as a preliminary to the possible success of such a campaign, which, of course, was absurd. The department further contended that before any very large sums were expended for attempts at extermination, the area of possible infestation should be delimited, at the same time pointing out the fact that no thorough scouting work for this purpose had yet been attempted. The wisdom of this stand was demonstrated in a striking way by the subsequent discovery of several additional extensive areas of long-standing infestation, remote from the original infested territory, which made it obvious that, had the large appropriations been expended for extermination within the areas first discovered, this money would have been largely, although perhaps not wholly, wasted.

Striking a Hard Blow.

The department had recognized from the first the potential danger of the corn borer as a pest to Indian corn, and when in the early part of 1919 a very considerable new area of infestation was discovered in east-central New York, indicating that the pest was much more widespread than had at first been supposed, it acted promptly by requesting the Sixty-sixth Congress to appropriate \$500,000 for immediate use in repressive work against the pest. The sum of \$250,000 was provided and became available July 24, 1919. With this sum in hand, the first adequate control and regulatory work of the department with this insect was begun. A large force of inspectors and scouts was thrown into the field, rendering fully effective the Federal quarantine which had been in force since August, 1918, and soon making available information upon which was based the subsequent extension of the quarantine regulations. Machinery was designed and built for the purpose of treating the most intensely infested areas with fire, steam, and other agents in order to retard or restrict the natural spread of the pest as much as possible. At the same time the research or experimental work to de-

termine the habits and natural history of the insect was pushed forward as rapidly as circumstances would permit. The newly discovered area of infestation in east-central New York was thoroughly explored and determined to be at least 500 square miles in extent. It is believed to have existed for at least seven or eight years and to have originated from a broom factory located near Schenectady.

The excitement caused by the discovery of the insect in New York culminated in a meeting of the National Association of Commissioners of Agriculture at Albany, N. Y., August 28, 1919. The direct result of this meeting was a resolution urging Congress to appropriate \$2,000,000 to carry on a combat with the corn borer. Believing that this demand largely exceeded the immediate needs of the work in hand, the department recommended an appropriation of \$500,000 and Congress responded by providing the sum of \$400,000, to be immediately available, and the present activities are being conducted with this money. Most of this is being expended in scouting operations and the enforcement of the quarantine regulations in the five States of the Union where the insect is known to occur. This work is a task of greater magnitude than is realized by the general public, involving as it does the employment of 200 or more inspectors during a large part of the year, distributed throughout most of the northern States. Some idea of the work involved may be conveyed when we say that more than 18,000 certificates of inspection were prepared and issued in a single day recently in the Boston area alone.

What It Means to the Corn Grower.

After reading all that has been said thus far, the corn grower may remark to himself: "This is all very well" (and if he is good-natured he may add "and interesting"), "but just what is this bug going to do to my corn? What is it going to cost?" Very good; let's look this incubus straight between the eyes.

In a field-corn growing region where the insect has almost certainly been present for approximately 10 years it occasions a direct loss of about $2\frac{1}{2}$ per cent of the kernels of all the ears. There is in addition to this an indefinite amount of indirect loss due to defective nutrition of the ears caused

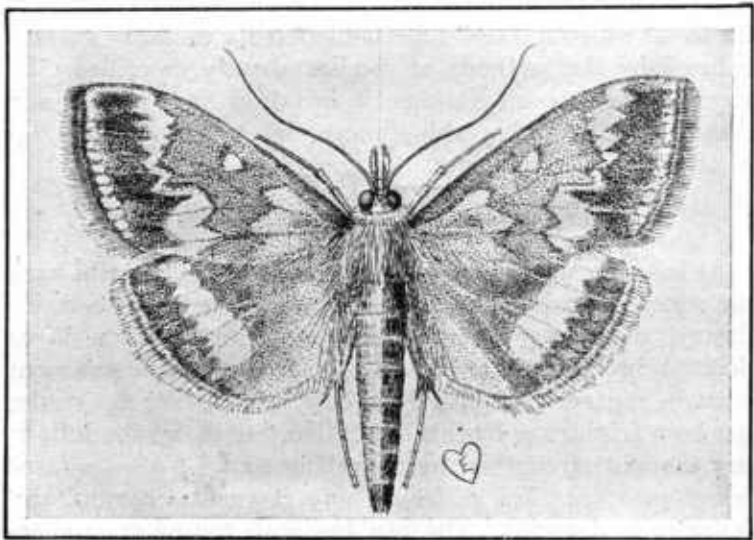
by the boring of the worms in the stalks as well as by breakage of the stalks, but none of these injuries has been serious enough to prevent the production of an excellent crop of corn in any field examined. This statement applies only to a region where the pest breeds but once a year, but it seems likely that the insect would have two breeding periods, or generations, throughout the southern half of the corn belt in the United States. To allow for this difference, suppose we more than double our estimate of the possible loss and assume that it might reach 7 per cent of the grain in two-thirds of the crop. That would mean an enormous loss in money with a crop such as was produced in 1920 of more than 3,000,000,000 bushels. At a possible market price of 85 cents per bushel this loss would reach the enormous figure of \$119,000,000.

But wait just a minute; we have disregarded entirely for the moment the fact that the losses upon which our estimates were based have occurred in a region where the pest has been *permitted to multiply unrestrained for a period of 10 years*. This can not happen in the corn-belt States, now that we know the habits of the corn borer, and for this reason the losses which it could inflict undoubtedly would be greatly reduced by the methods of combat already described. In view of these considerations, it certainly does not appear that the pest would be able, in any case, to destroy the crop of any progressive farmer.

No Decisive Victory for the Pest.

At least one man of science has gone into public print with the statement that if the pest is not eradicated "the corn industry, together with everything that depends on it, is doomed in North America," etc. This gloomy statement must be regarded as pure hyperbole, and in case the reader has been frightened by this or similar visions, let the following thought strengthen his wavering soul. *No introduced insect pest ever has destroyed any important agricultural industry in America.* The San Jose scale caused great losses to the deciduous fruit industry for many years, but it has been largely instrumental in the production of better fruit and in securing better prices for that fruit. The Mexican

cotton boll weevil has done great damage to the cotton crop of this country for a very considerable period, but cotton is still a major crop in the infested regions, and at least one community has erected a monument to the boll weevil as a benefactor, in forcing diversified farming upon a region that was sorely in need of this innovation. The Hessian fly, which came here late in the eighteenth century, is the worst insect pest with which our wheat growers have to contend, taking a toll of 10 per cent of the crop, but it has not prevented us from becoming one of the two greatest wheat-producing nations on the globe, and no pesky caterpillar from overseas is going to be permitted to deal a knock-out blow to that greatest of all American agricultural institutions, the corn crop—"not so you can notice it!" But, as with the older pests, so with this new one, we shall be compelled to fight long and hard.



The Male Moth.